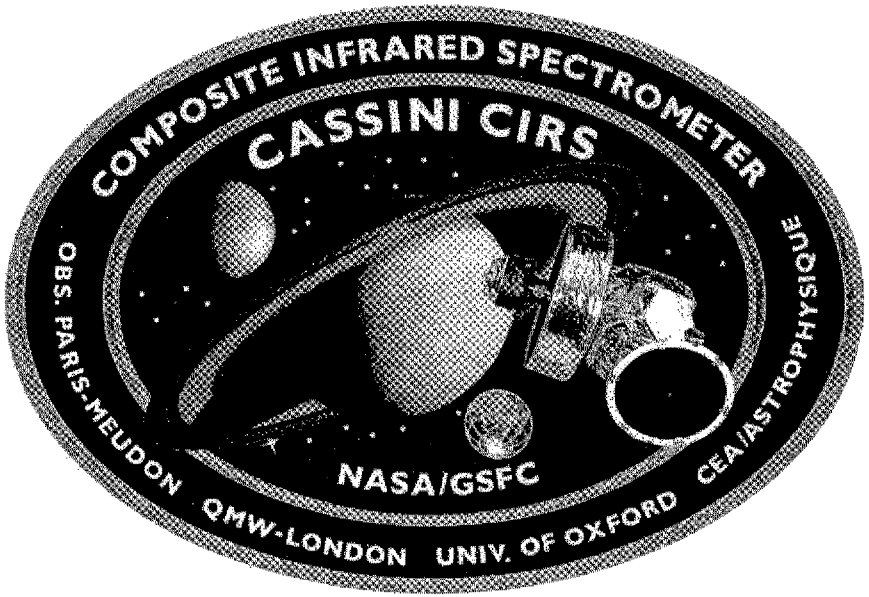
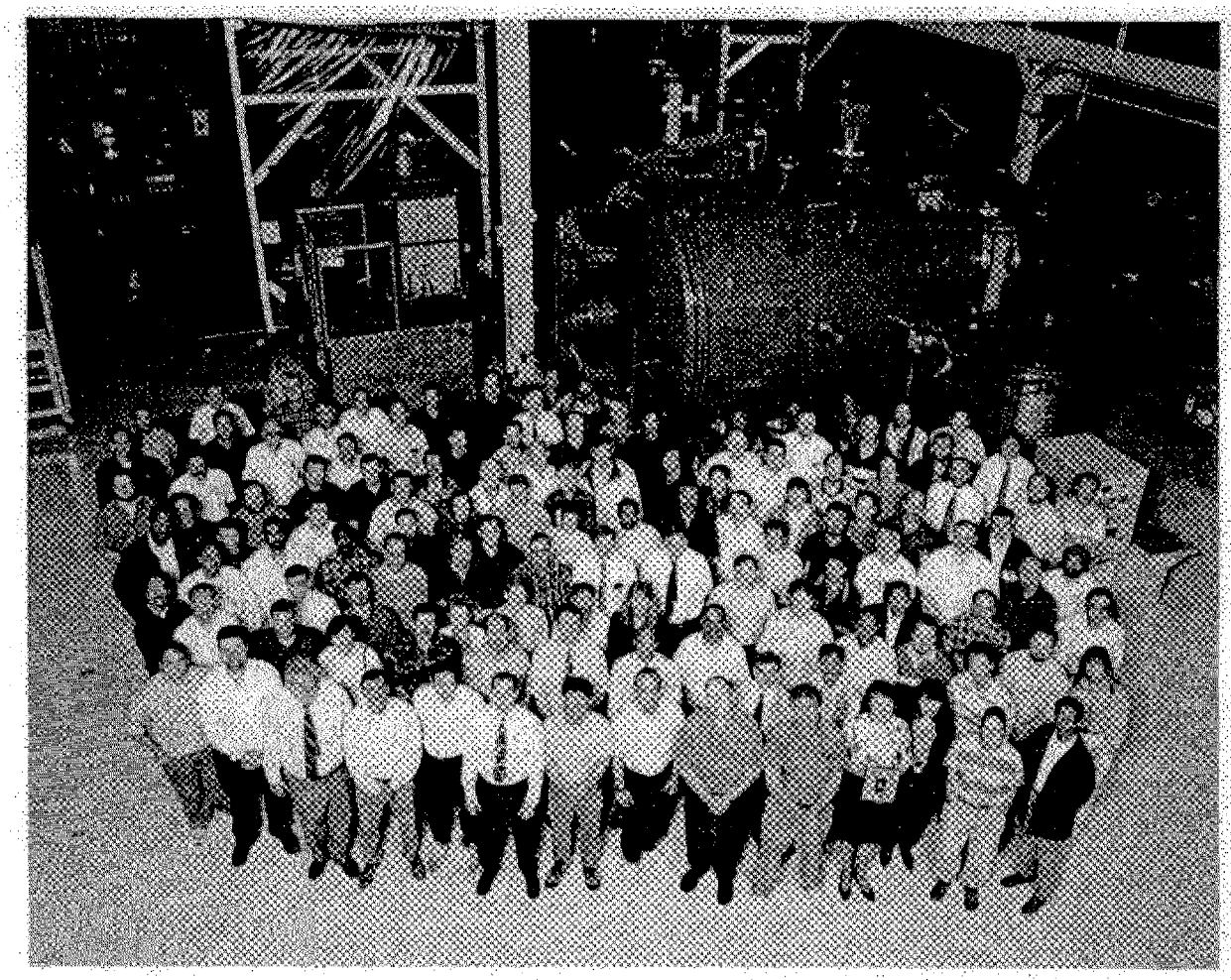
The Thermal Infrared Investigation on Cassini: A Challenge for Laboratory Studies



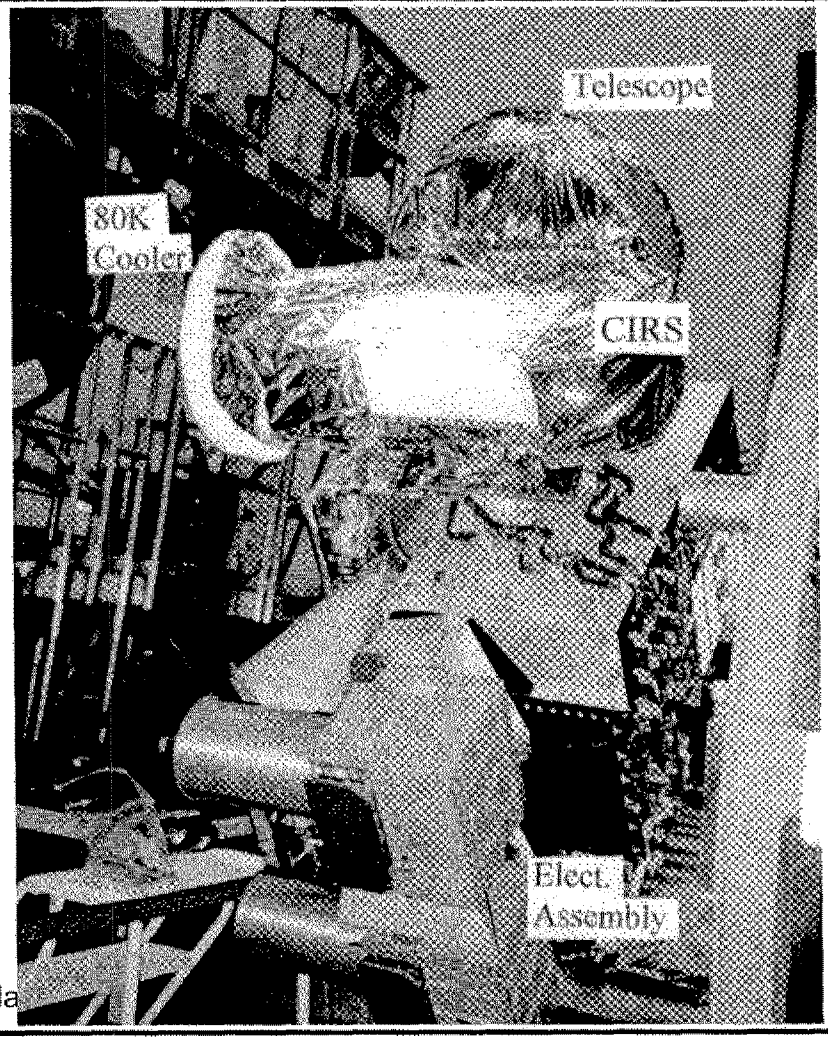
D.E. Jennings, C.A. Nixon, F.M. Flasar, V.G. Kunde and A. Coustenis

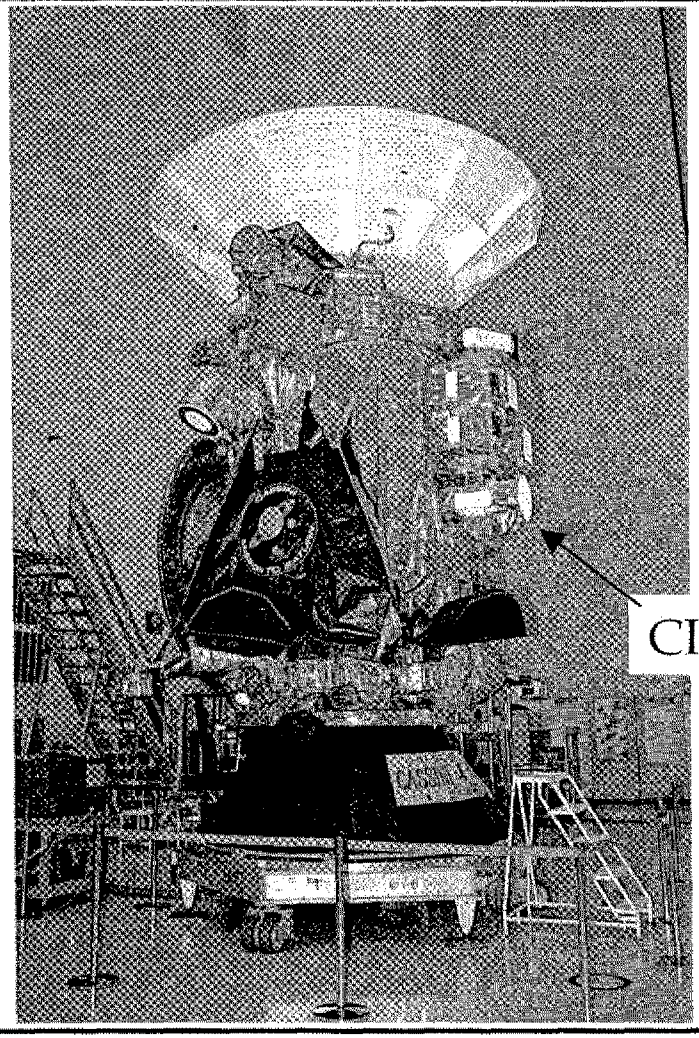
Presented at
EGU 2010: Spectroscopy and Radiative Transfer in Planetary Atmospheres
Vienna, 5 May 2010

CIRS Development Team at Goddard in 1996

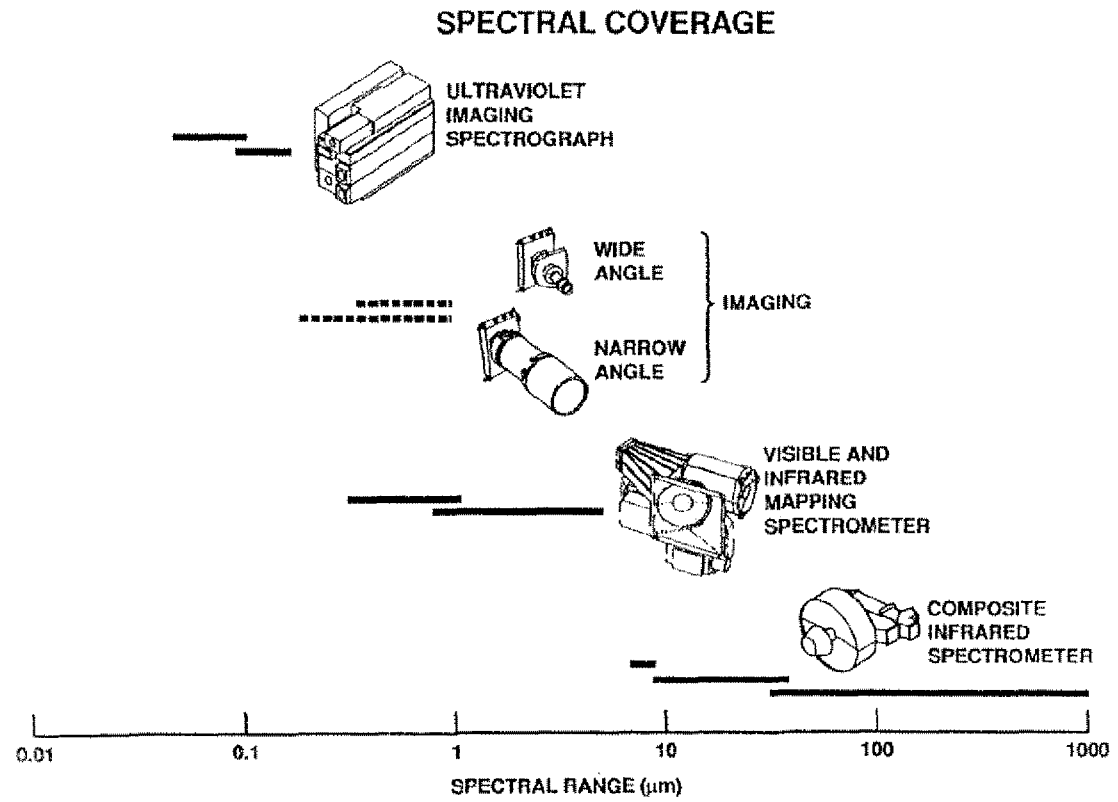


Location of CIRS on Cassini





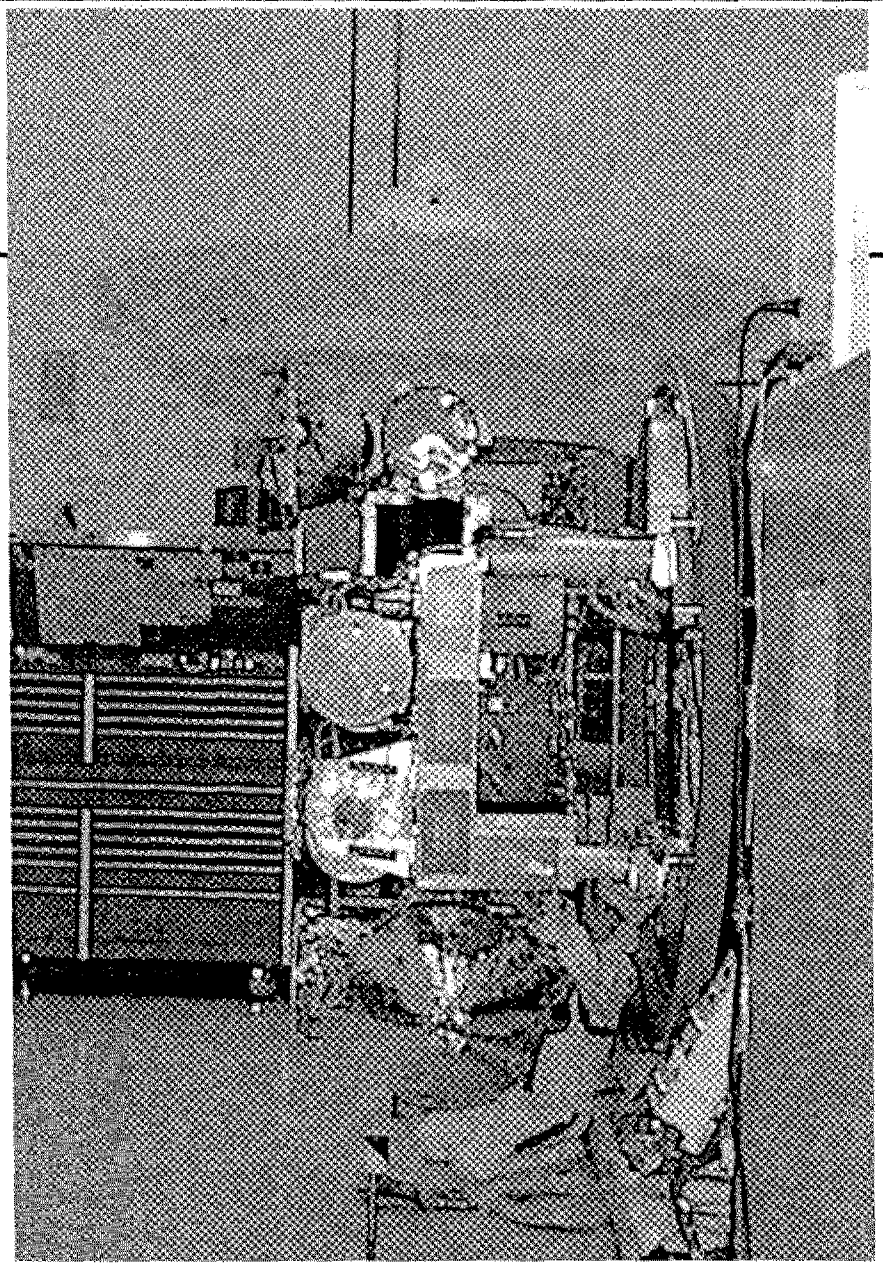
CASSINI REMOTE SENSING SPECTRAL COVERAGE



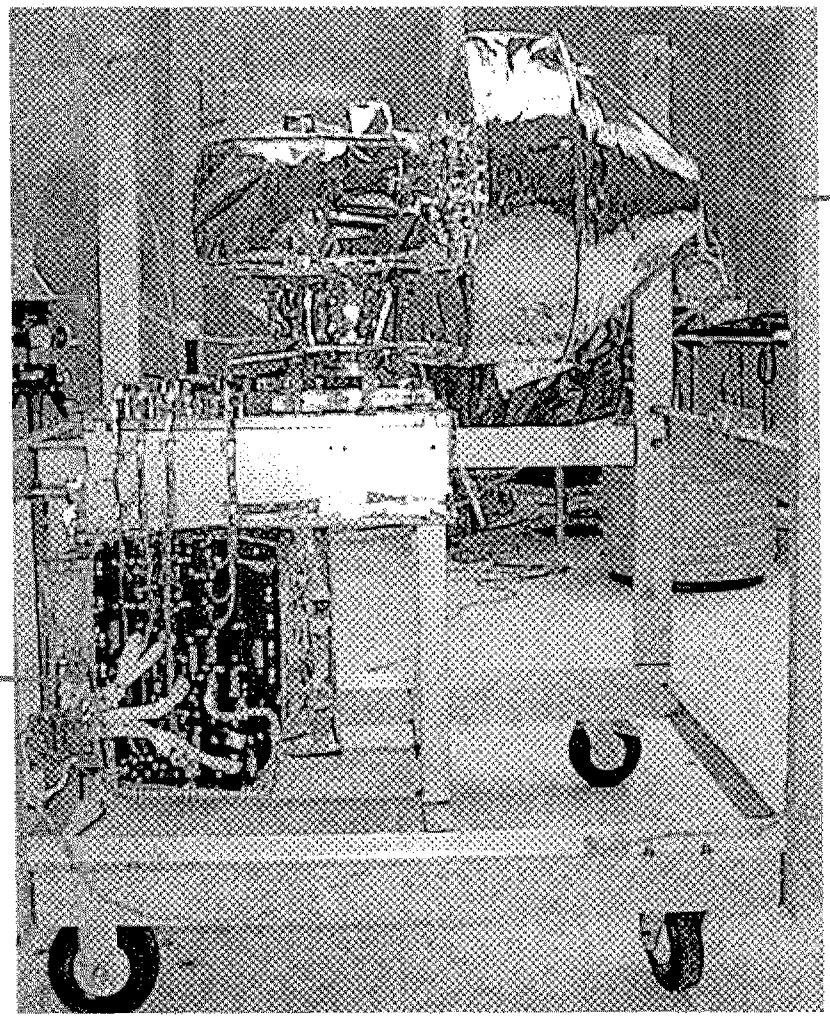
Instrument Description

Telescope Diameter (cm):	50.8		
Interferometers:	FAR-IR	MID-IR	
Type:	Polarizing	Michelson	
Spectral range (cm^{-1}):	10 - 650	600 -1450	
Spectral range (microns):	15.4 - 1000	6.9 -16.6	
Spectral resolution (cm^{-1}):	0.5 to 20	0.5 to 20	
Integration time (sec):	2 to 50	2 to 50	
FOCAL PLANES:	FP1	FP3	FP4
Spectral range (cm^{-1})	10 - 650	600 - 1125	1100 - 1450
Detectors	Thermopile	PC HgCdTe	PV HgCdTe
Pixels	2	1 x 10	1 X 10
Pixel FOV (mrad)	3.9	0.273	0.273
Peak D*(cm $hz^{1/2}$ W^{-1})	4 x 10^{9}	2 x 10^{10}	5 x 10^{11}
Data Telemetry Rate (kbs)	2, 4		
Instrument Temperature (K)	170		
Focal Planes 3 & 4 Temperature (K)	75 - 90		

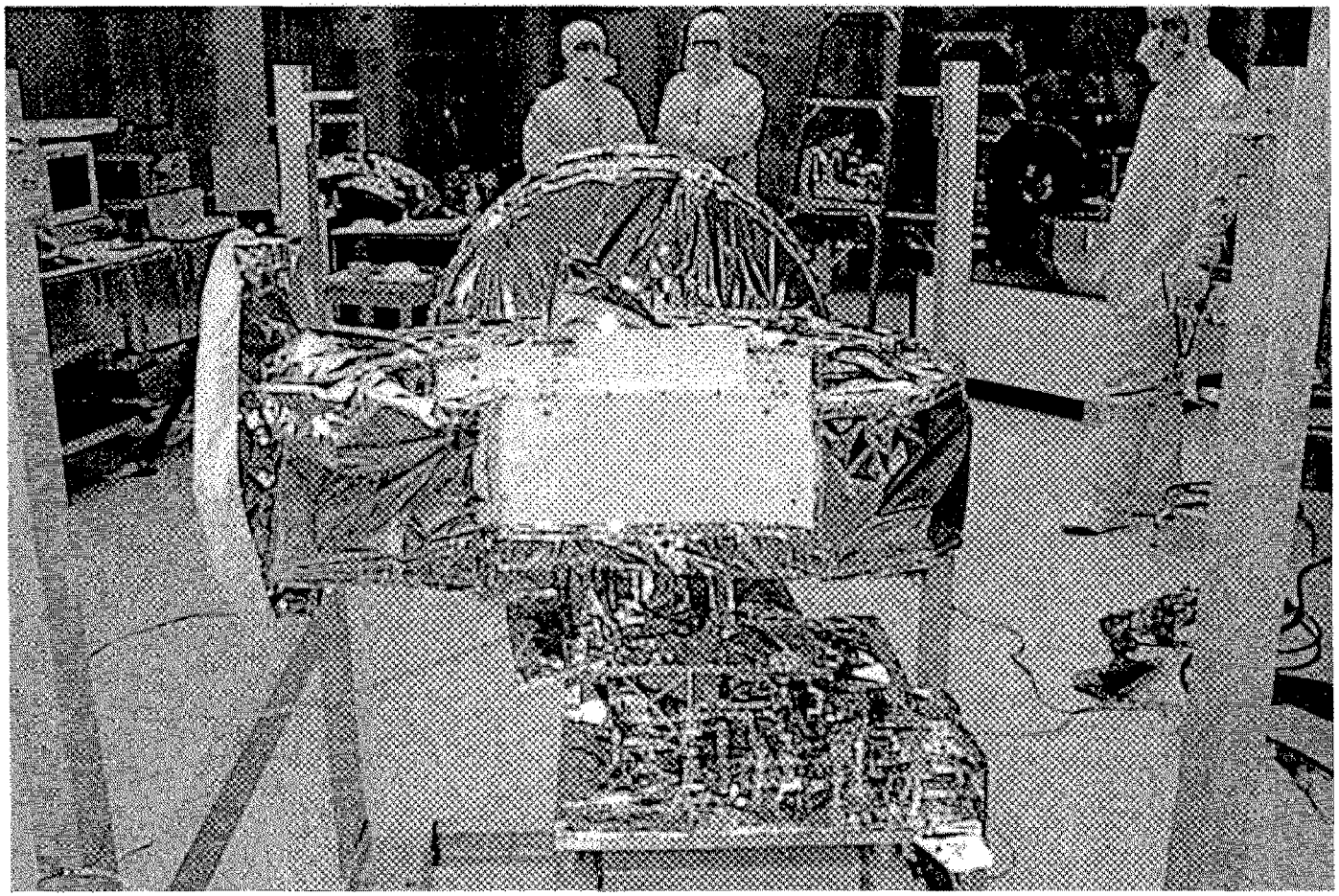
CIRS on RSP



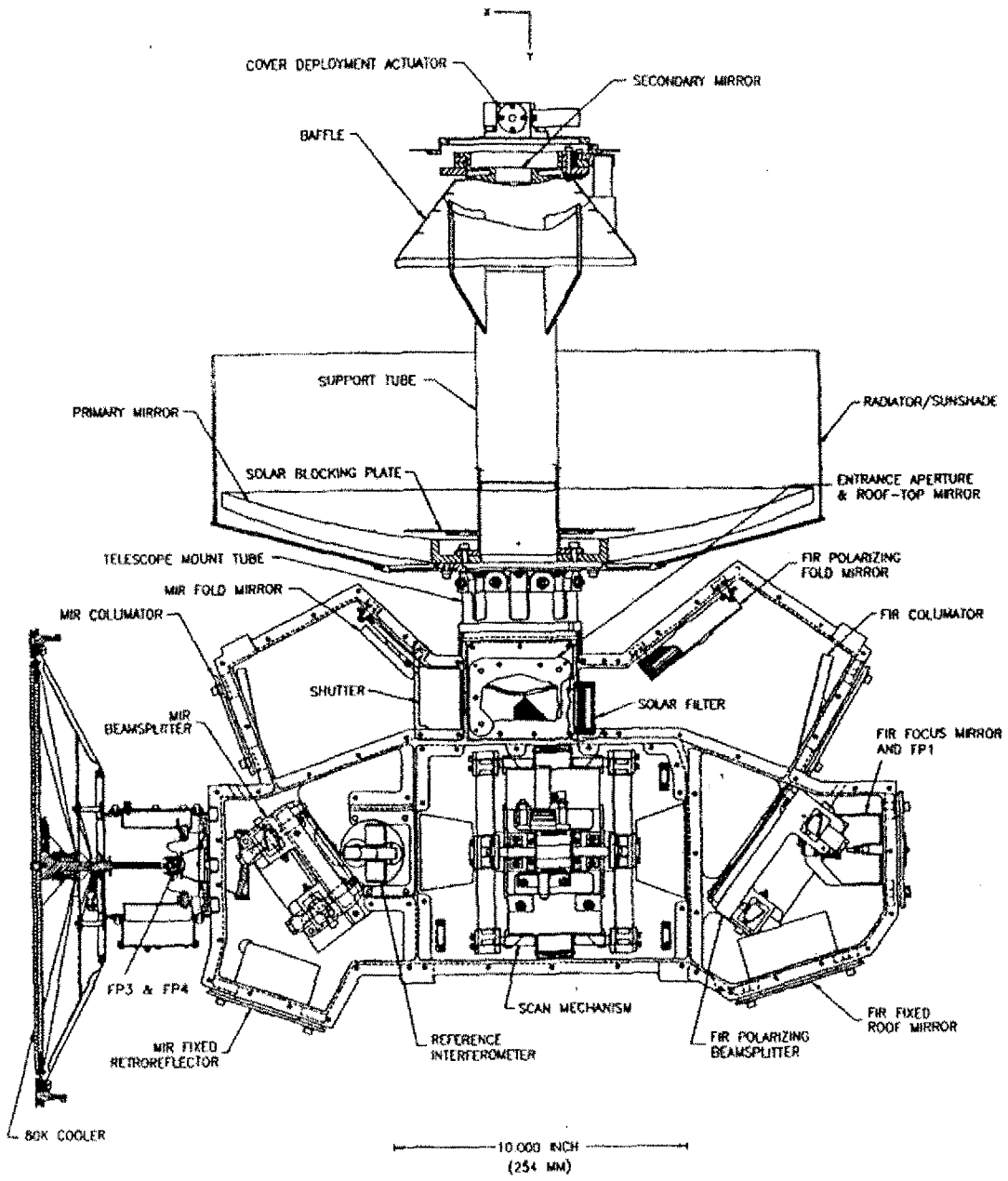
CIRS Ready for Thermal-Vacuum Testing



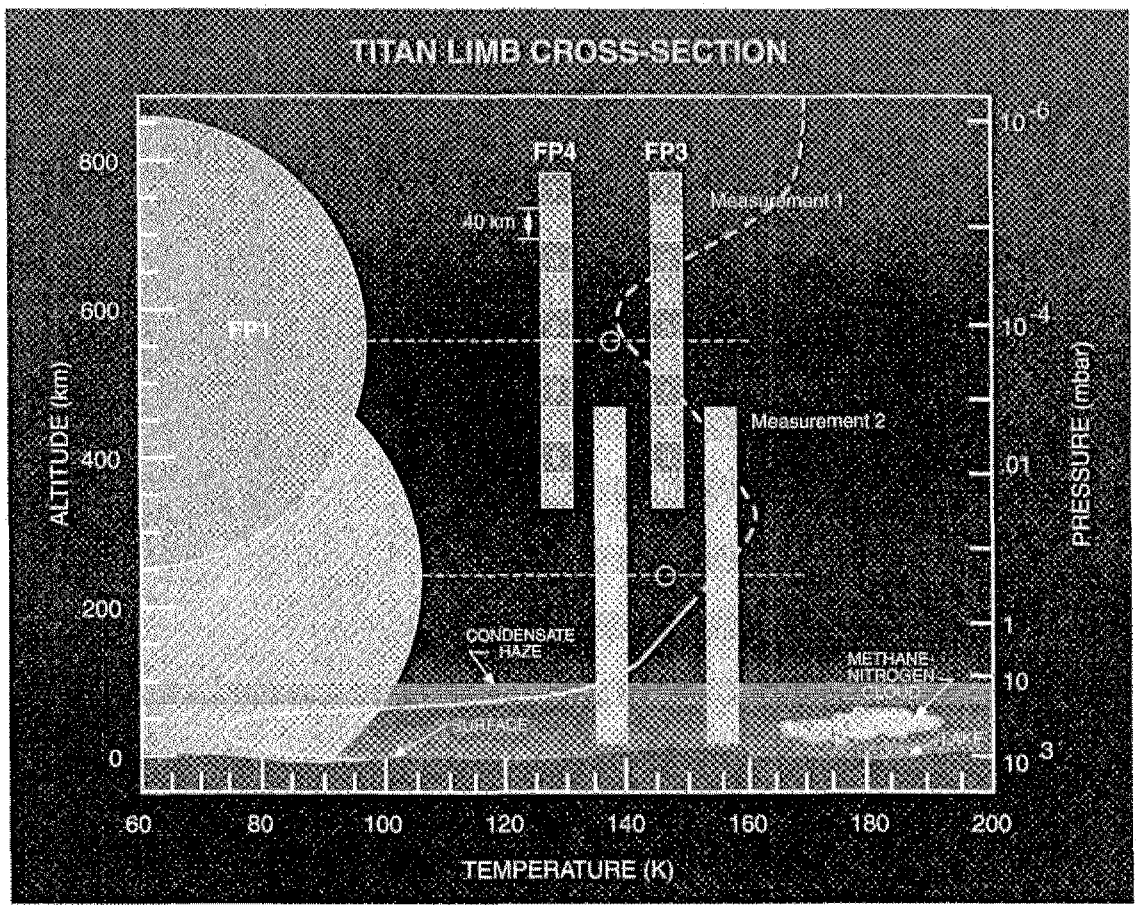
CIRS' Backside



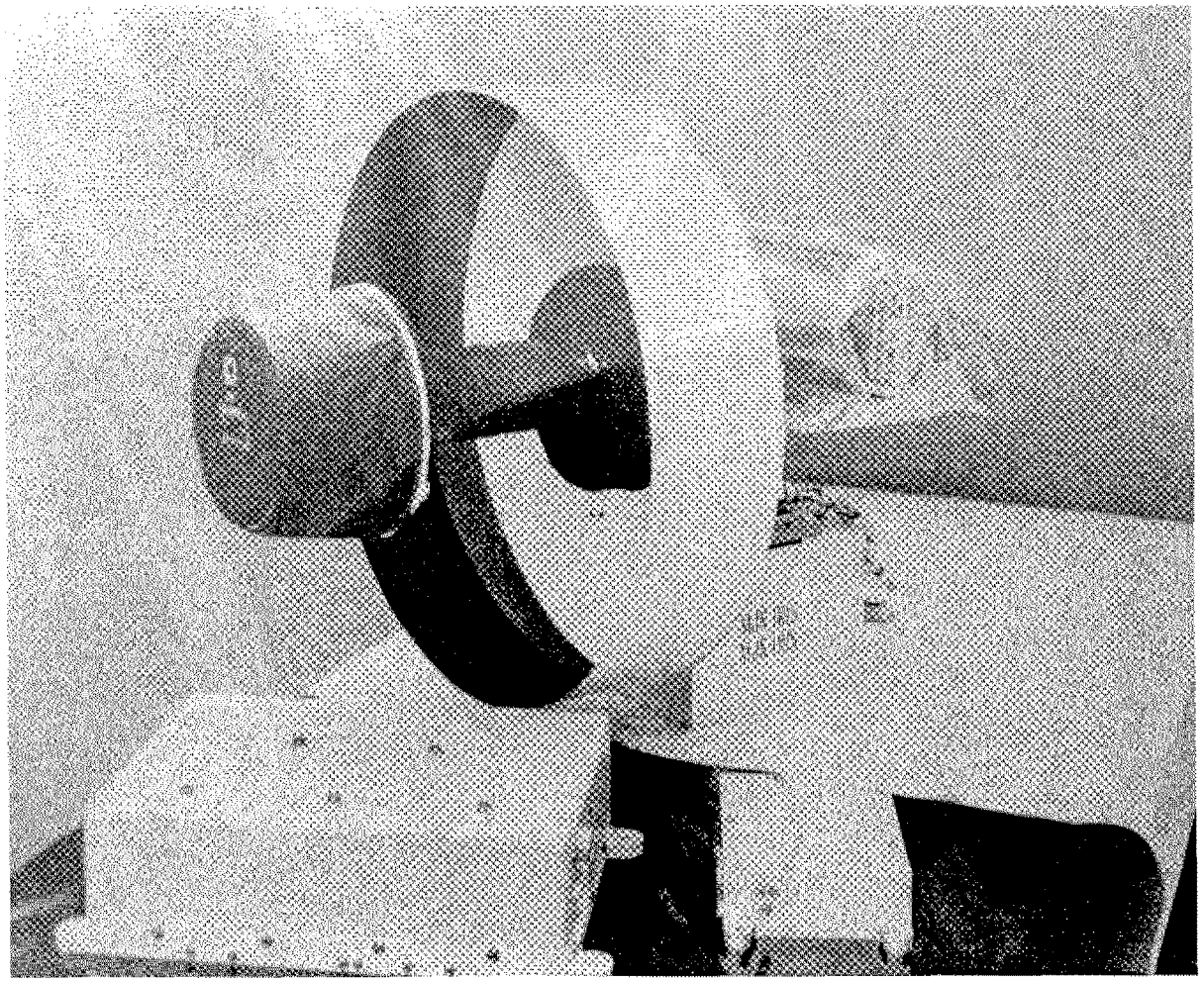
CIRS Mechanical Layout



CIRS FOV's Projected on Titan's Limb



Voyager IRIS



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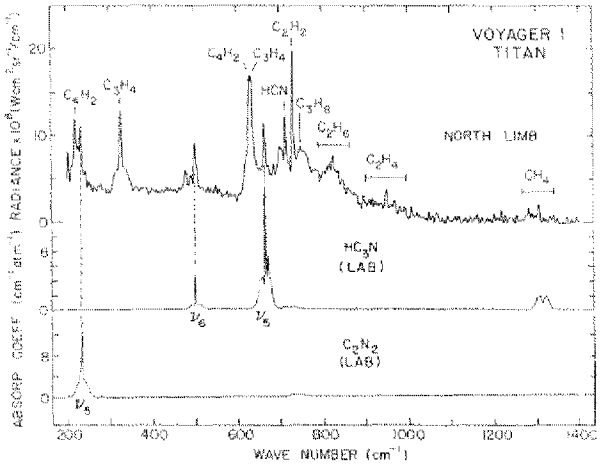
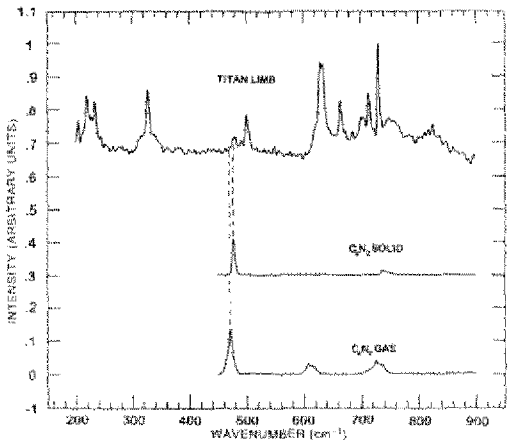
Laboratory spectroscopy and Voyager IRIS

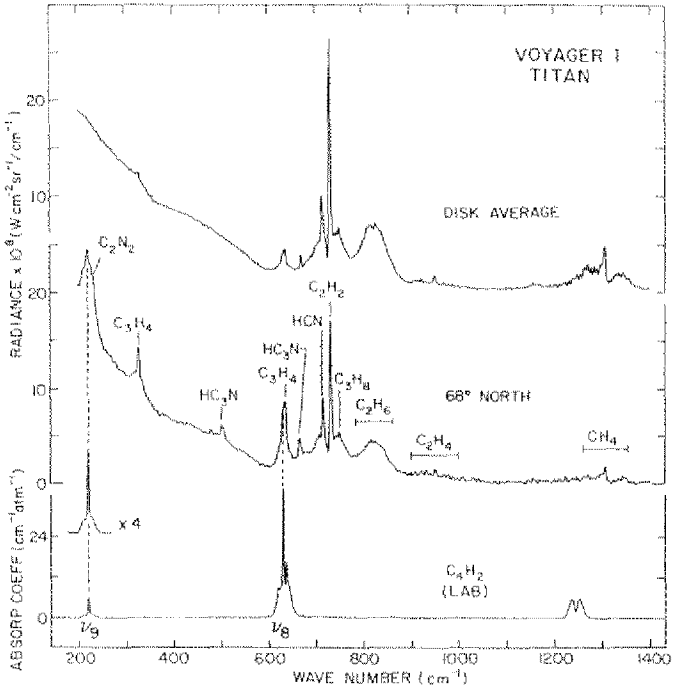
HC_3N

C_2N_2



C_4N_2





C_4H_2

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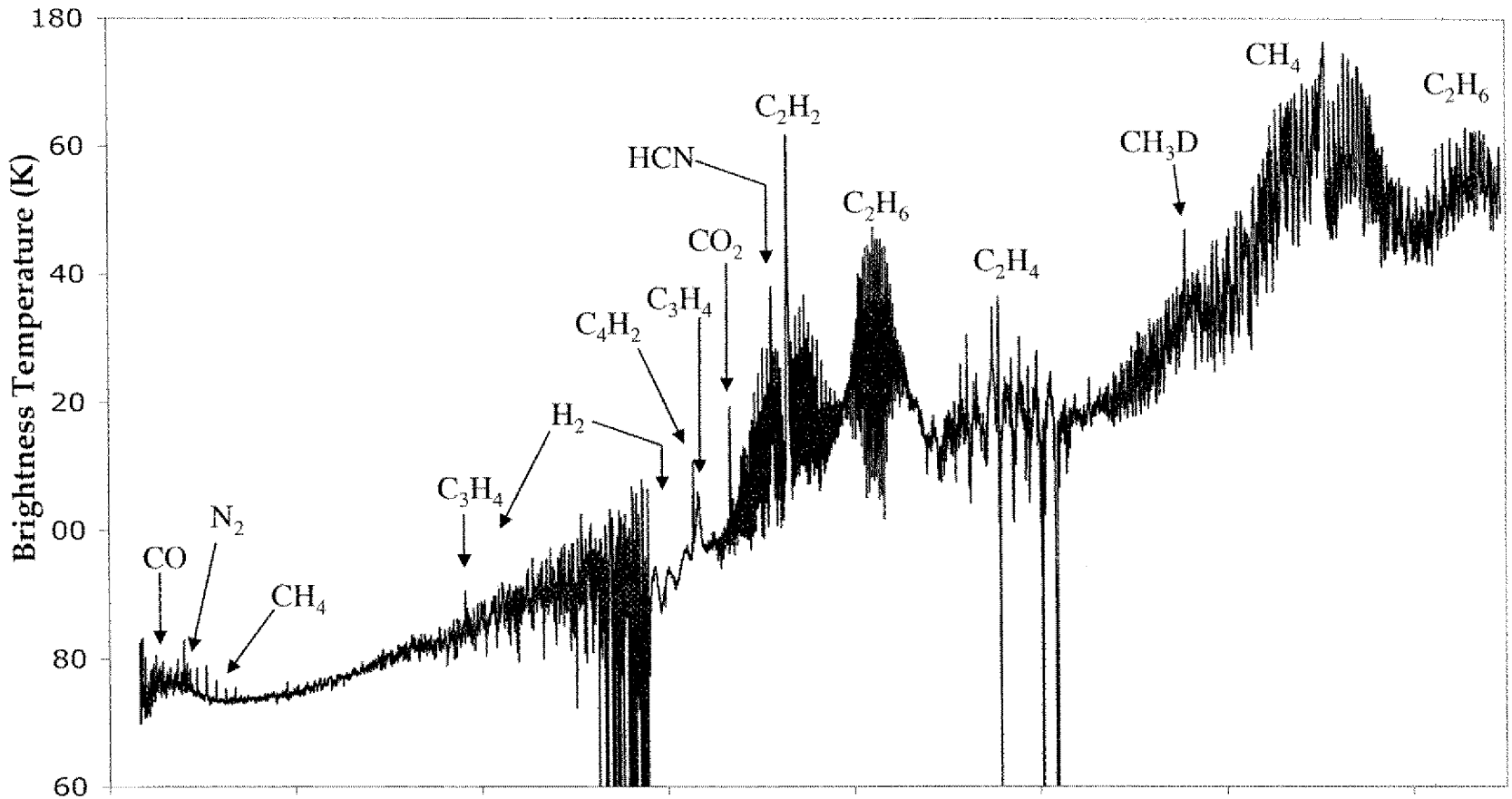
Composite Brightness Temperature of Titan



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dej-13

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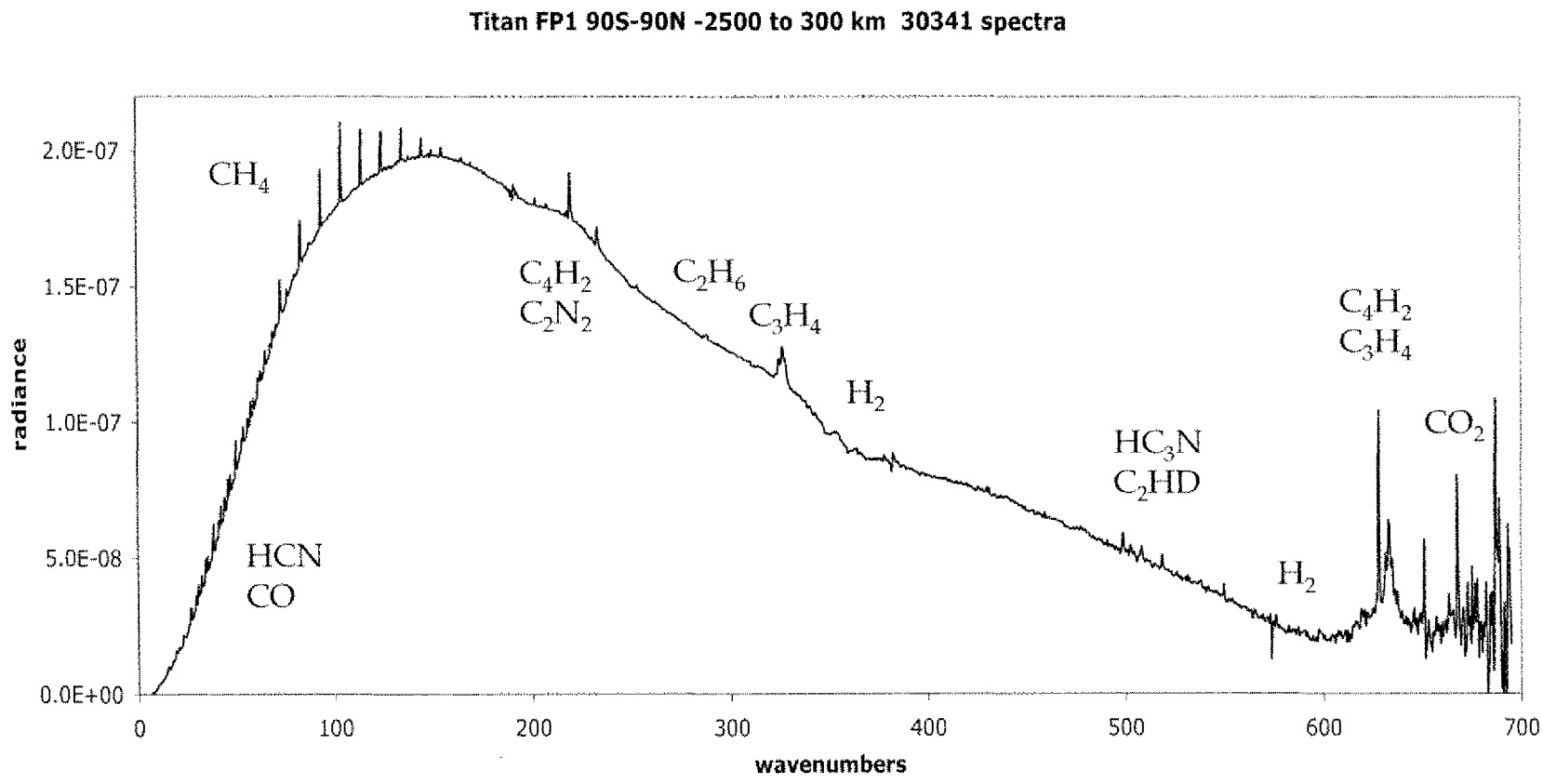
Titan FP1 Large Average



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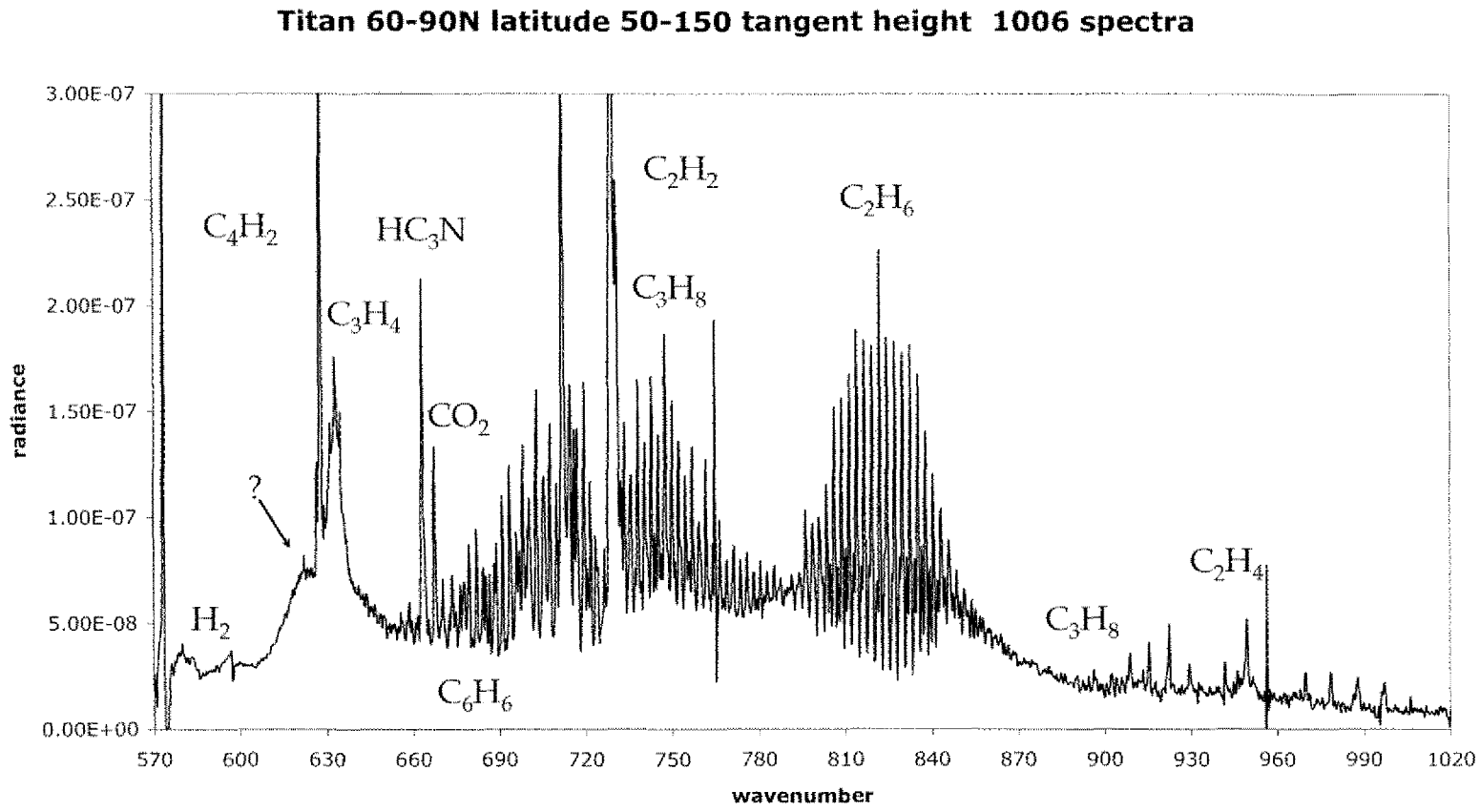
Titan FP3 Large Average



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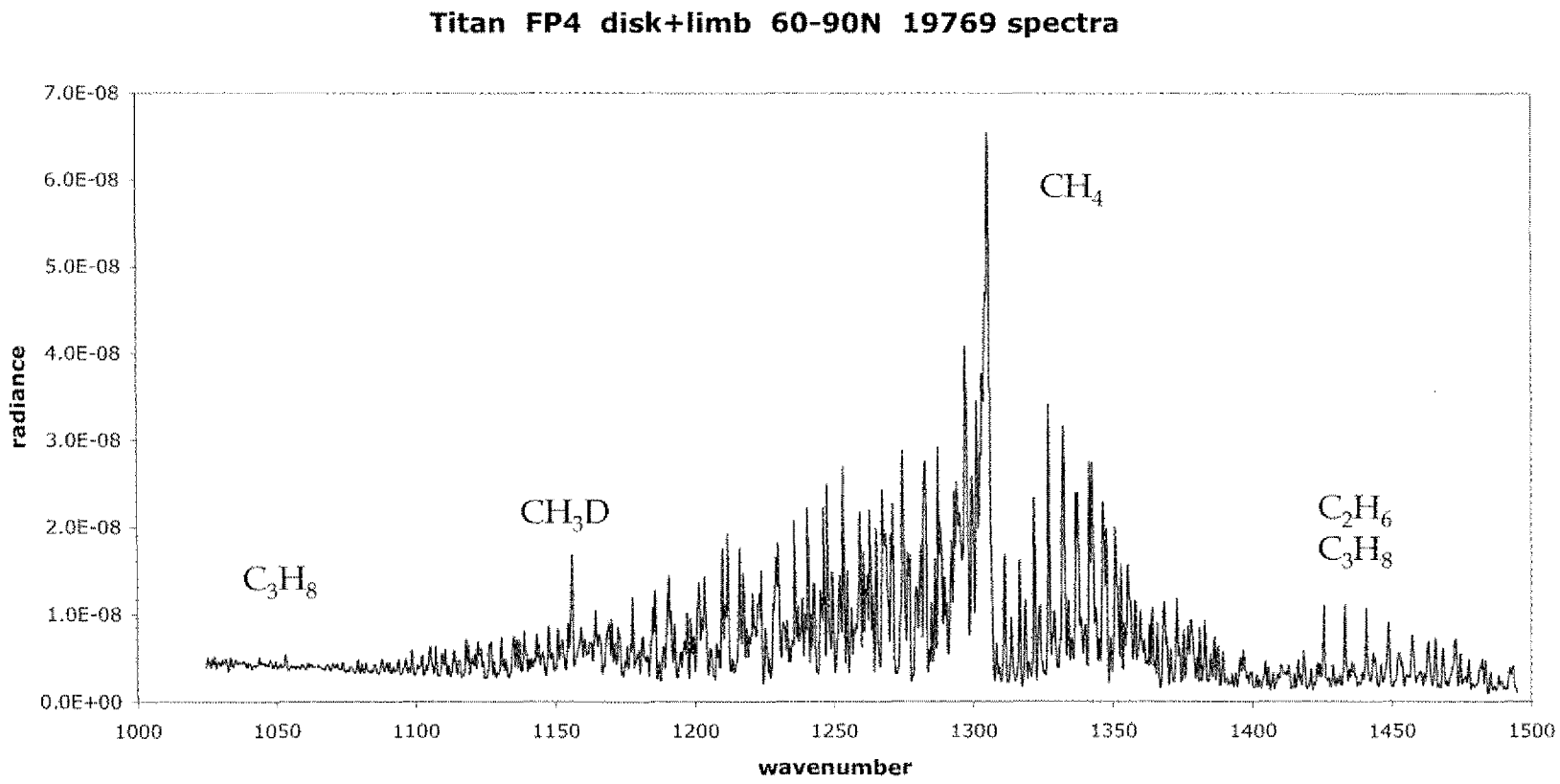
Titan FP4 Large Average



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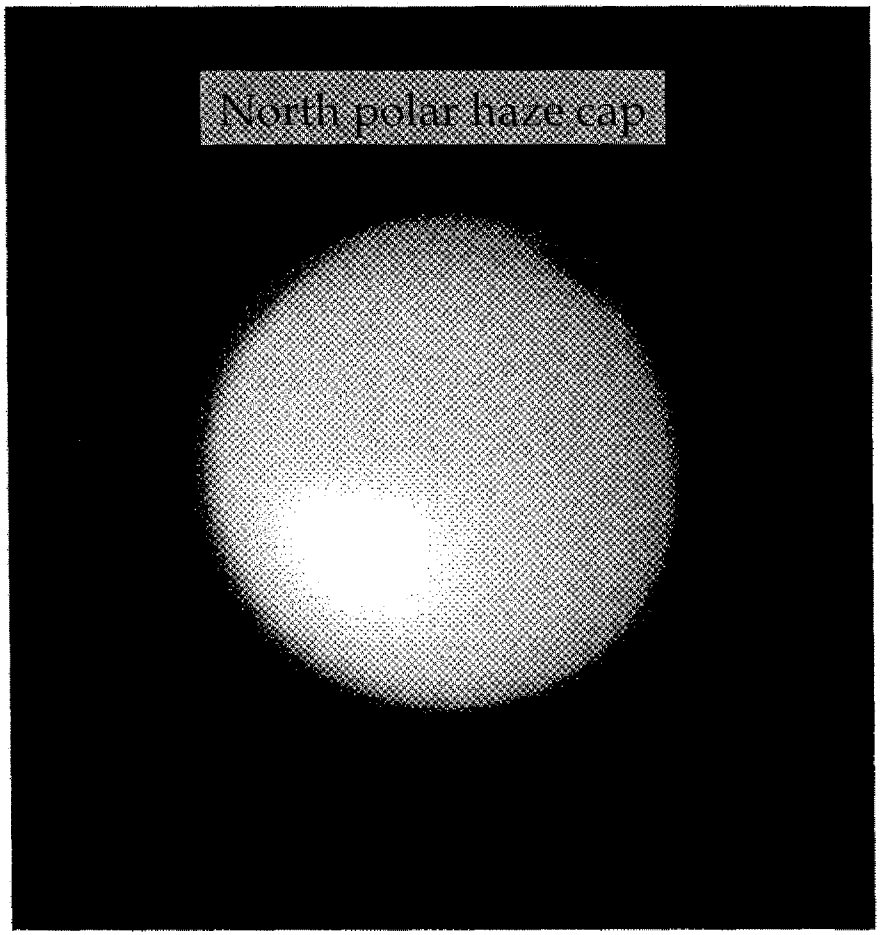
Titan's Atmospheric Haze



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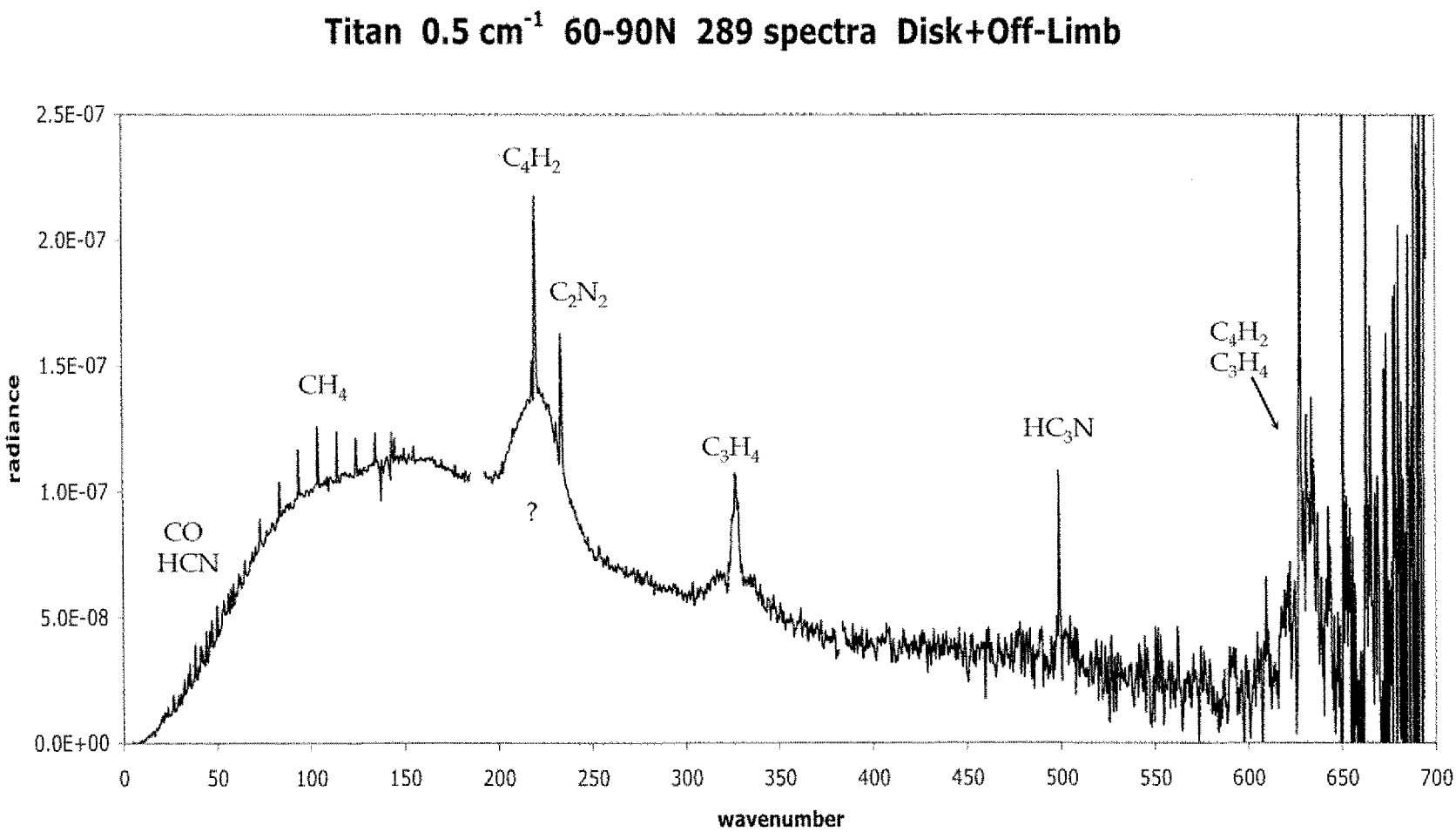
CIRS FP1 spectrum at 0.5 cm^{-1} resolution



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dej-18

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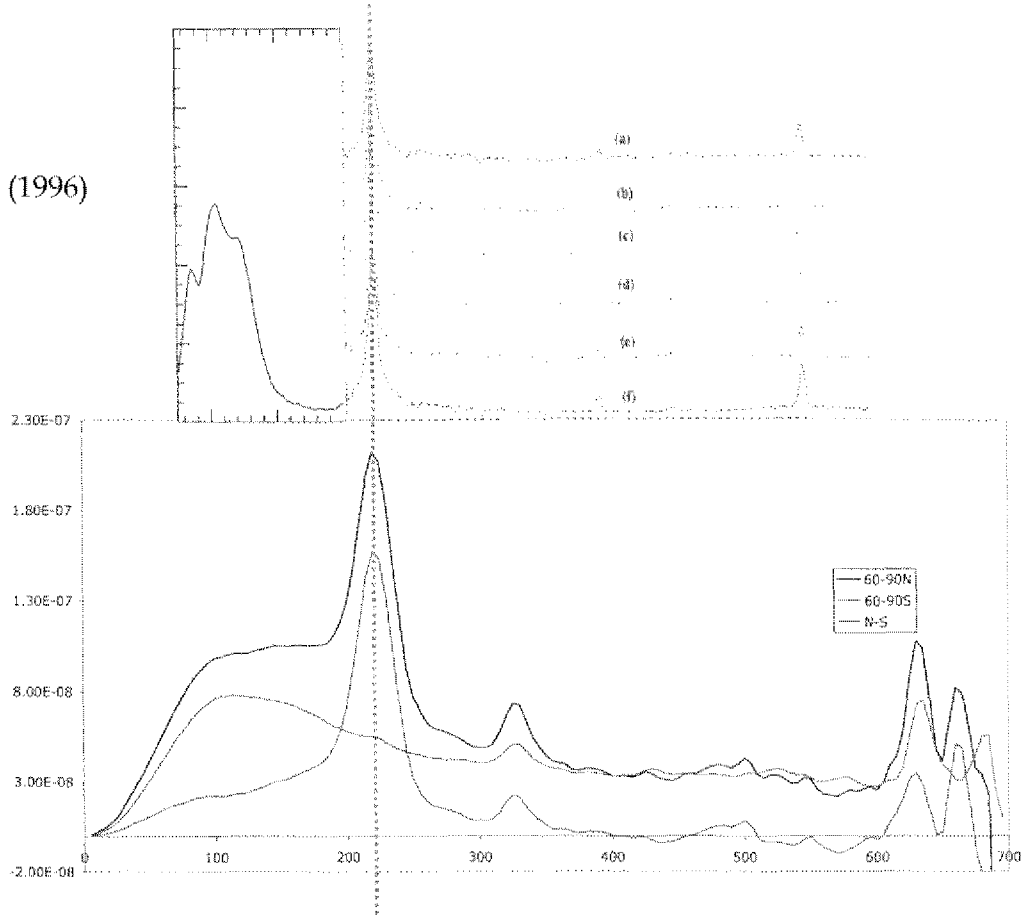
Solid Propionitrile as a candidate for 200 cm^{-1} feature

Laboratory
Crystalline CH_3CH_2CN
DelloRusso & Khanna, Icarus 123, 366 (1996)
Khanna, Icarus 177, 116 (2005)

Titan
CIRS



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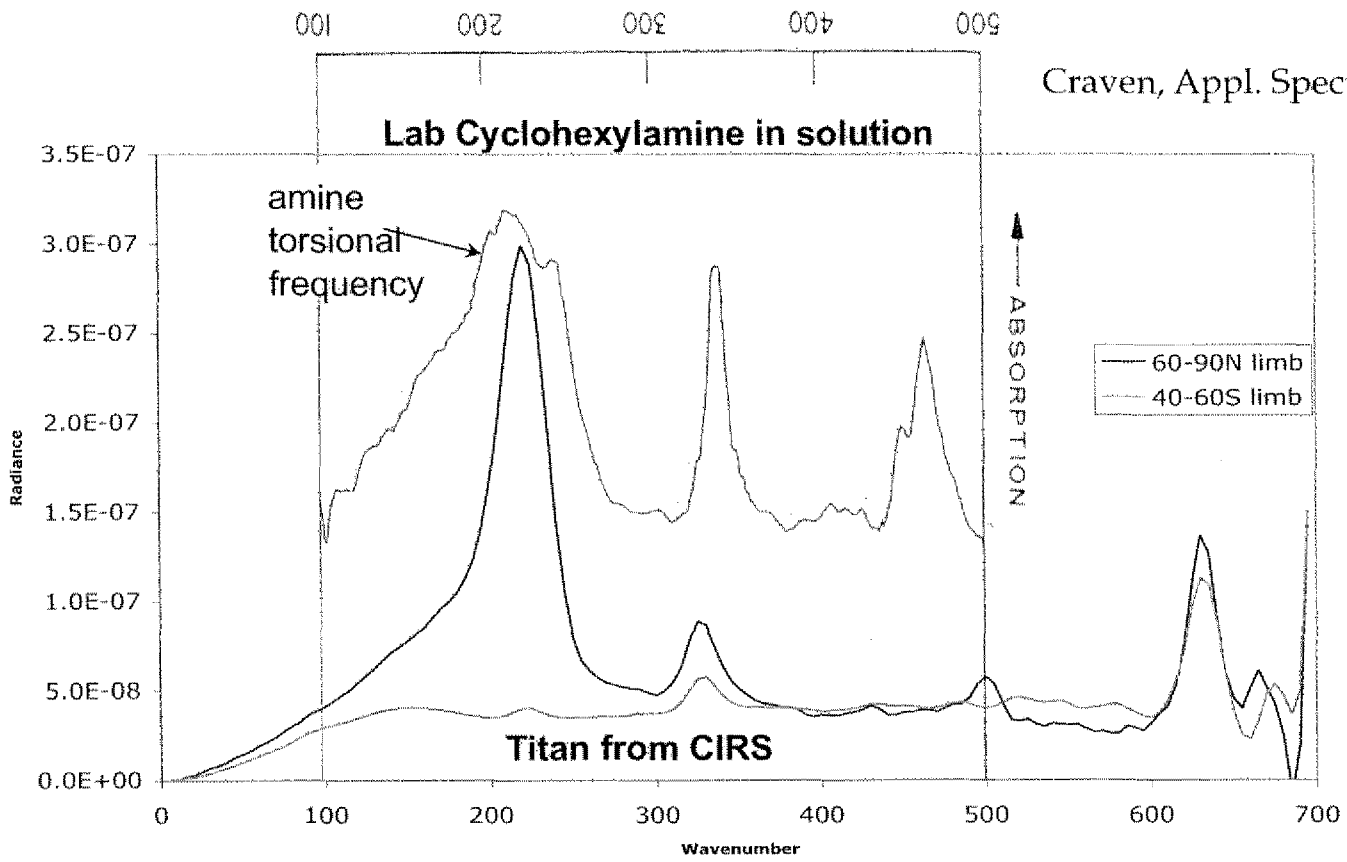
Amine torsional group frequency as a candidate for 225 cm^{-1} emission feature



Craven, Appl. Spect. 26, 449 (1972

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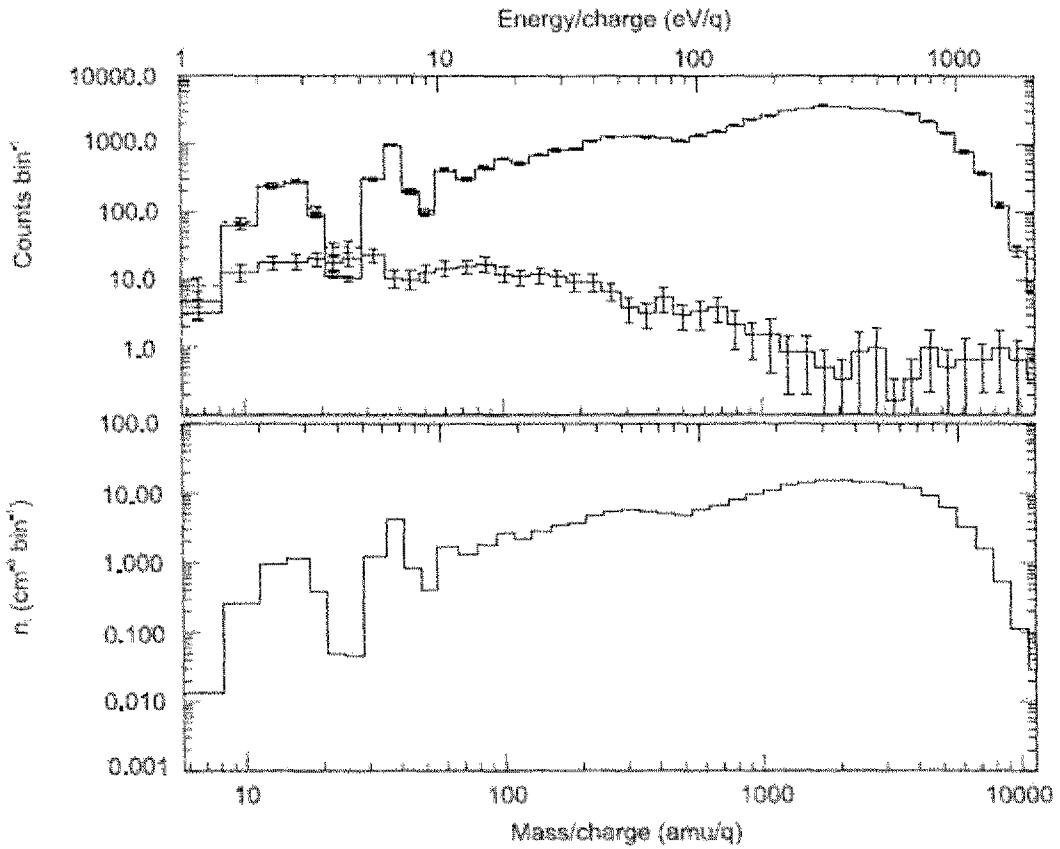
Do group frequencies on heavy molecules contribute to the infrared spectrum?

"Discovery of Heavy Negative Ions in Titan's Ionosphere"
From Cassini CAPS; Coates *et al.*, GRL 34, L22103 (2007)



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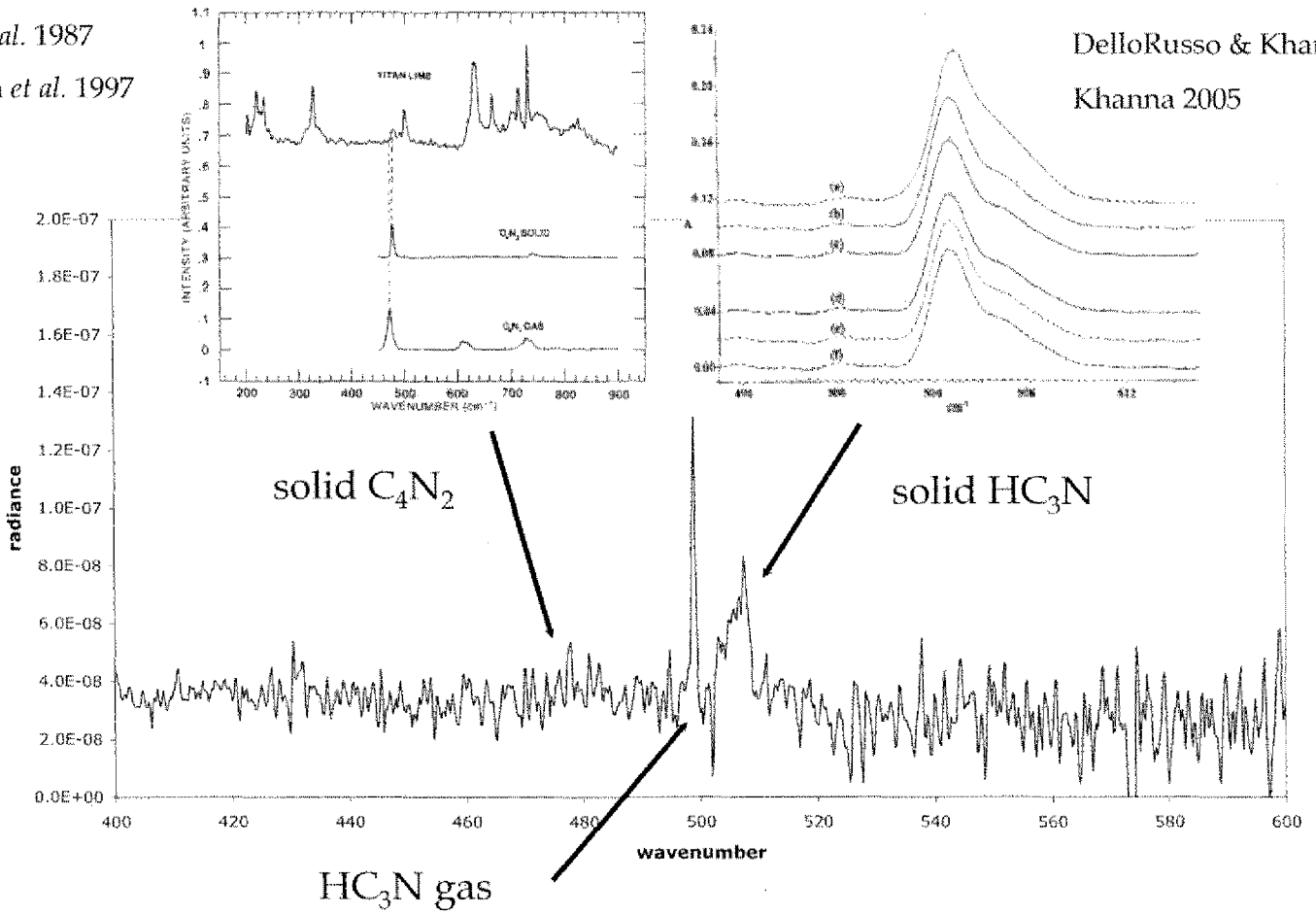
Identifications of condensed species in Titan from laboratory studies

Khanna *et al.* 1987

Samuelson *et al.* 1997

DelloRusso & Khanna 1996

Khanna 2005



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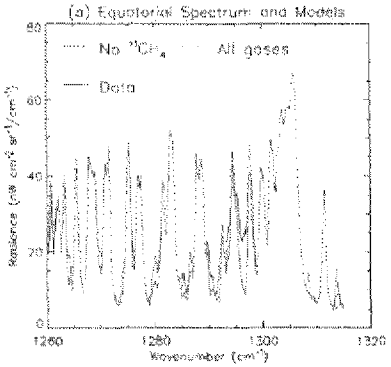
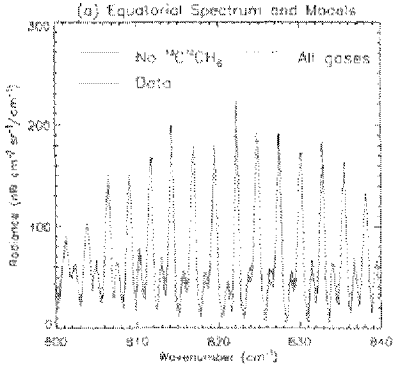
Carbon isotope enrichment on Titan varies among molecular species

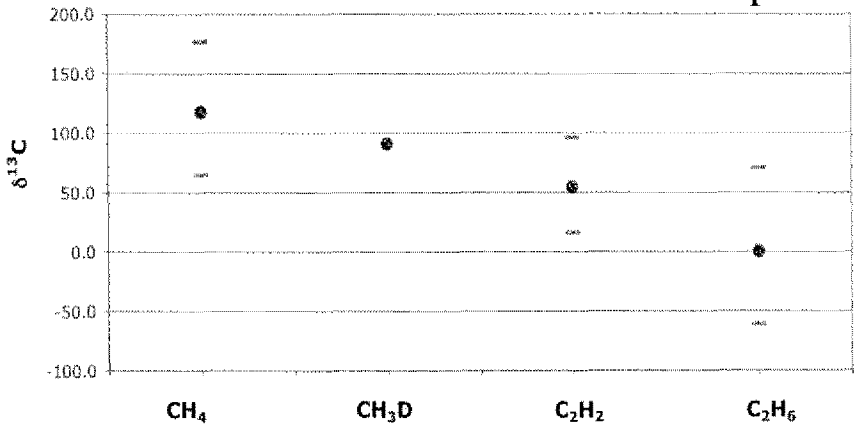
Methane from CIRS





Ethane from CIRS

Carbon-13 Enrichment in Titan' Atmosphere



- Ethane is the main product of the destruction of methane.
- Ethane is ~10% depleted in ^{13}C compared to methane.
- Ethane's $\delta^{13}C \sim 0$ is close to telluric and Solar System values.

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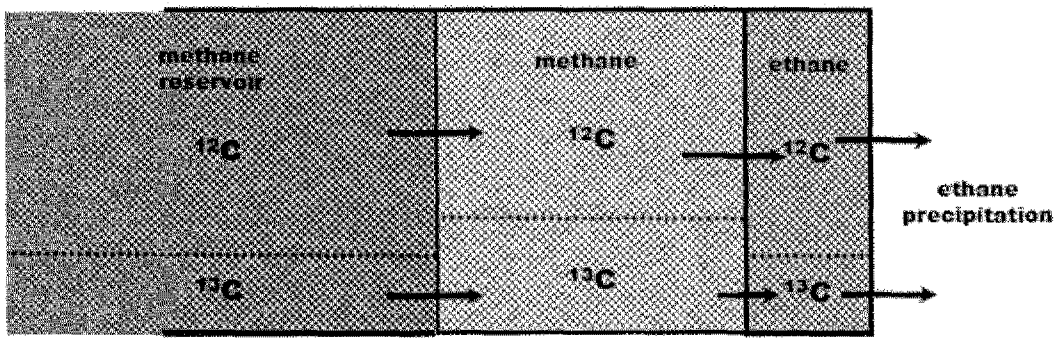
Is the $^{12}C/^{13}C$ enrichment in ethane caused by the kinetic isotope effect?

assume steady-state



$$\left.\frac{^{12}C}{^{13}C}\right|_{\substack{reservoir\\methane}} \approx KIE \bullet \left.\frac{^{12}C}{^{13}C}\right|_{\substack{atmosphere\\methane}} \approx \left.\frac{^{12}C}{^{13}C}\right|_{\substack{atmosphere\\ethane}}$$

- Ethane is formed from methyl (CH_3), which comes from methane dissociation.
- At 200-300 km methyl is formed through $CCH + CH_4 = C_2H_2 + CH_3$.
- The kinetic isotope effect (KIE) might generate the observed ^{12}C enrichment in ethane over methane.
- The near-zero ^{13}C-enrichment in ethane implies a primordial origin for the methane reservoir.
- The KIE in $CCH + CH_4 = C_2H_2 + CH_3$ has not been measured in the lab.

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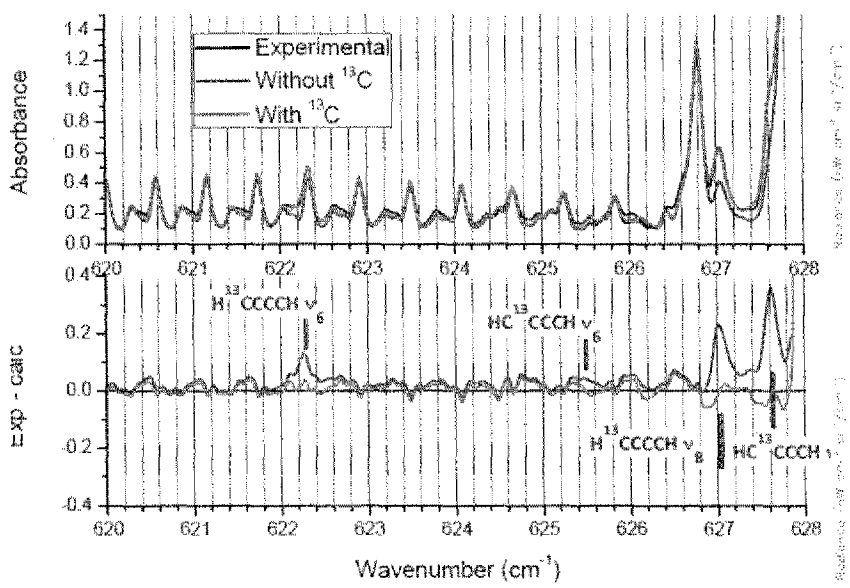
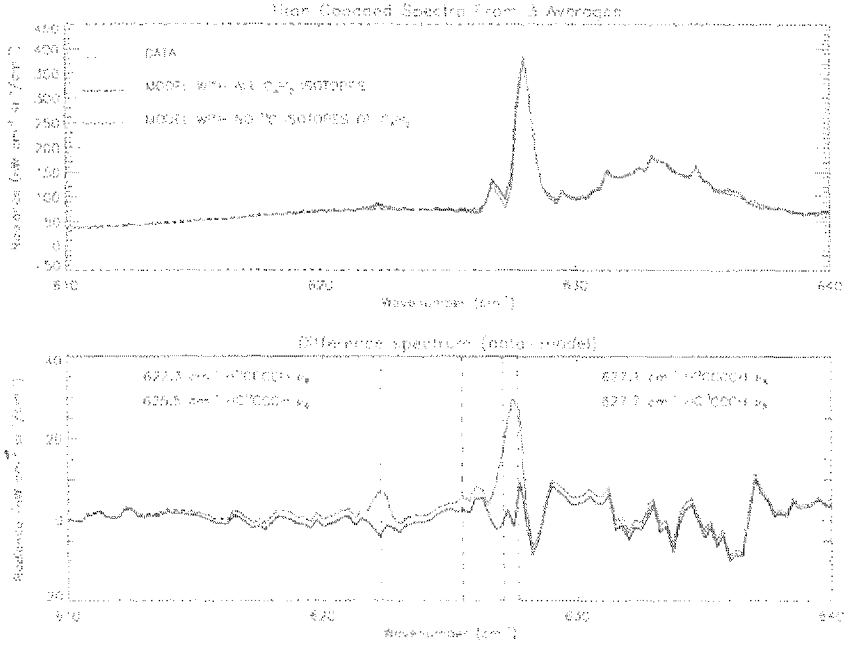
Isotopic species: identification of ^{13}C-diacetylene in Titan from laboratory measurements

CIRS



Laboratory spectra of $H^{13}CCCCH$ and $HC^{13}CCCH$



Titan from CIRS observations

Jolly *et al.*, *Astrophys. J.* 714, 852 (2010).

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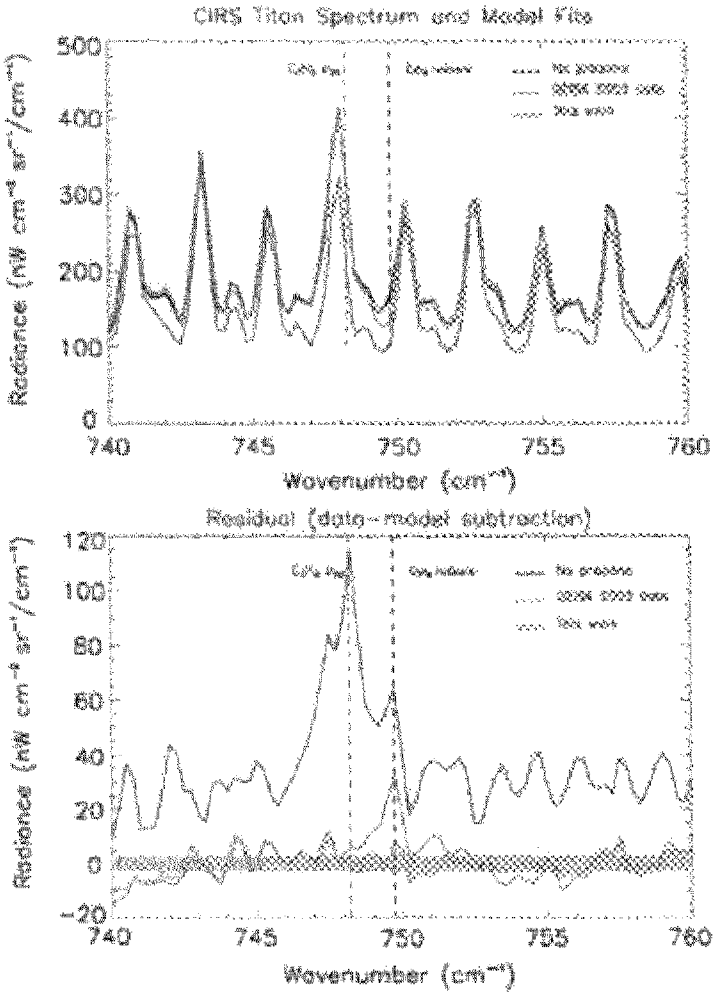
Modeling Titan's spectrum requires improved molecular parameters



Missing C_3H_8 hot band in earlier model later fit with improved linelist from laboratory spectroscopy.

Flaud *et al.*, *Molec. Phys.* in press, (2010)

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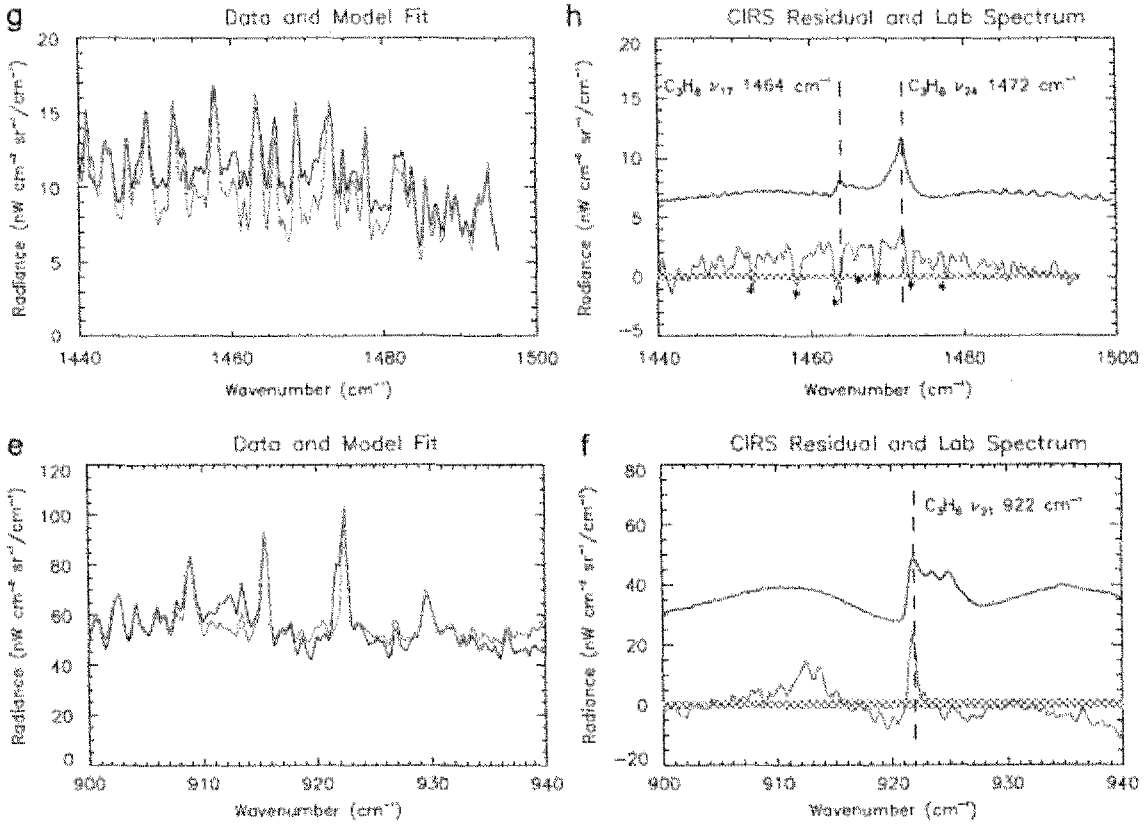
Need for improved molecular parameters from laboratory measurements



1460 cm^{-1} region.
Model residual
compared with
C_3H_8 lab spectrum.

Pseudo linelist used
For C_2H_6 ν_7.

920 cm^{-1} region.
Model residual
compared with
C_3H_8 lab spectrum.

Low temperature
Spectra needed.

Nixon *et al., Plan. Sp. Sci.* 57, 1573 (2009).

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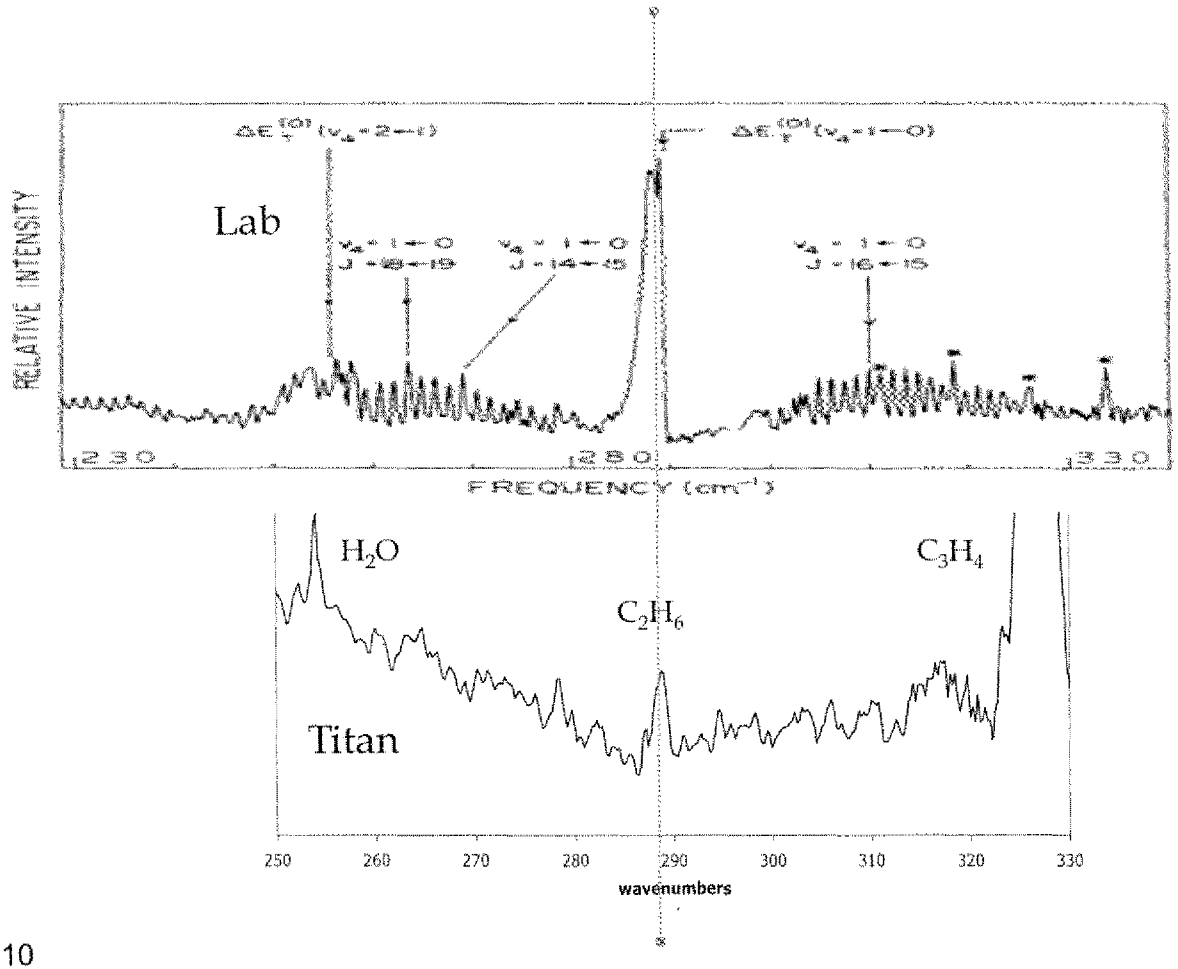
Ethane ν_4 Torsional Band at 288 cm^{-1} in Titan



Moazzen-Ahmadi *et al.* 1988, JCP, 88, 563.